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UNIVERSITY OF LONDON, UNIVERSITY COLLEGE

A CENTURY'S PROGRESS IN PHYSICS

An Address delivered by
SIR OLIVER LODGE, F.R.S.
on Monday, March 14, 1927

SIR GREGORY FOSTER
IN THE CHAIR

Being the Second of a Series of Centenary Addresses

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A CENTURY'S PROGRESS IN PHYSICS

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BY

SIR OLIVER LODGE, F.R.S.

Being the Second of a Series of

CENTENARY ADDRESSES

SIR GREGORY FOSTER

(Provost of the College)

IN THE CHAIR

Delivered on Monday, March 14, 1927

LONDON

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A CENTURY'S PROGRESS IN PHYSICS

THE CHAIRMAN: My Lords, Ladies and Gentlemen, this is the second of a series of Centenary Addresses. The purpose of those Addresses is to review, as far as may be possible, the progress of the various branches of work that have been carried on within these walls during the last hundred years, and to review in that connection the contribution of this College.

We have to-night as our guest a very old friend, Sir Oliver Lodge. (Applause.) There is no need to introduce him to you. He is a son of this College. He was a member of the staff under Professor Carey Foster, and he went away from us, as the term is, to "better" himself, to the welfare, first of all, of the University of Liverpool and, later, to become the distinguished Head of the University of Birmingham.

It is a great joy to us to see him here among us again. I call on him to give us his Address on "A Century's Progress in Physics."

SIR OLIVER LODGE: Sir Gregory Foster, Ladies and Gentlemen, this place is not unknown to me. I have lectured in this room before, and I was in this College for seven years. Indeed in the Slade

H.C.M.

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School I found one who is with me still, and who is going to celebrate with me in the autumn our Golden Wedding. I had not intended to begin with a personal note; but you tempted me, Sir.

When this College was founded as the University of London (and I wish that it had continued with that title)—it was before my time—it was founded to liberate higher education from the trammels of sectarian bigotry and to free it from theological privileges and tests. For that very reason it encountered a good deal of hostility at its birth.

The condition of education at that time, in the beginning of last century, seems to have been deplorable. I did not, and do not, know of the condition by my own knowledge; but you, Sir, addressed the Union about a year ago, taking a very large and wide scope on all manner of subjects, many of which are quite unknown to me, and gave a history of the College, from which we can learn much. From that Address I want to make two short quotations. One is from Sir John Herschel, who, speaking of the condition of education at the time when this College was founded, said: "The end of the eighteenth and the beginning of the nineteenth century were remarkable for the small amount of scientific movement going on in this country. Mathematics was at its last gasp, astronomy nearly so. The chill torpor of routine had spread over all those branches of science which wanted the excitement of experimental research." I do not know that we are quite satisfied with the condition of education in this country now. I do not feel quite happy about the public schools, perhaps because I know too little about them.

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Anyhow, the fillip of scientific research has been given by this College and by other Institutions, so that now, though we may not be satisfied, we have made immense progress.

Such progress for this College was anticipated by the other quotation which I will read. It is a quotation from Henry Morley's History of the College. It was a so-called prophecy, a literal anticipation, in *The Edinburgh Review* of February 1826: "We predict that the clamour by which the foundation of this College has been assailed will die away, that it will be destined to a long, glorious, and beneficent existence, that while the spirit of its system remains unchanged the details will vary with the varying necessities and facilities of every age, that it will be the model of many future establishments" (It is pretty good to have said that in 1826. It was a long time before it took effect; but it has been the model of all the provincial Universities which have grown up since), "that even those haughty Foundations which now treat it with contempt"—we need not know what "haughty Foundations" he was referring to—"will in some degree feel its salutary influence, and that the approval of a great people to whose wisdom, energy and virtue its exertions will have vastly contributed will confer on it a dignity more imposing than it could derive from the most lucrative patronage or the most splendid ceremonial." I see more ceremonial to-night than I had expected. I would have garbed myself in proper costume had I known.

The difficulties which it encountered were great. Its poverty, after it ceased to be the University of

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London, was depressing. There were benefactors; but still it suffered greatly for lack of funds. The things it did were wonderful, under the circumstances. But there was no State aid. State aid came in when, in my own time and indeed in this present century (I am not speaking for this College alone but of all provincial Universities), the State began to wake up to the need of education. What woke it up? I am inclined to think that it was the Education Act of 1902, an Act which was carried through by that enlightened Statesman, Earl Balfour, inspired and guided by that powerful administrator, Sir Robert Morant. Since then the progress has been rapid. I believe that you have trebled the number of staff, trebled the number of students, and trebled the laboratory floor space.

Much more remains to be done. I said that the Government had wakened up. It has not fully wakened up. If the people of this country realised what education could do for the country and how important it was, we should be able to hold our heads up among the nations of the world in a way which occasionally is a little difficult. America seems to have got most of the funds of the world, and administers them lavishly and with considerable success. Germany—I am not referring to recent events—was setting us a good lesson in the way in which the State supported education and in the way in which investigation was supported and scientific development was going on. Fortunately, there are enlightened firms that are waking up and are realising the value of research. Such laboratories as those of the General and Western Electric

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Companies, and so on, are turning out results of great importance.

When I came here in 1874—it was January 1874, I think—I came in the middle of the struggling period. Laboratories were only just beginning. Of course there was the Chemical Laboratory; but the Engineering Laboratory was not there, and the Physical Laboratory was only just in its infancy. Professor Carey Foster initiated one, or at any rate one of two. I think that this was the first one to be initiated for a students' Laboratory in Physics. He only had two small rooms for the purpose. He began under great difficulties; but that has blossomed into what we now know. Physical Laboratories were then only just beginning. Sir William Thomson had a laboratory in Scotland; but in England, I believe, this was the first.

Retrospect on Physical Science

My subject is the progress of physics, physical science, during the century. I propose to try to sketch, by taking a typical instance, the kind of developments which have gone on.

The branch of physical science which was dominant in the world in the year 1826 was the wave theory of light. The wave theory of light began with that century. It was just in the heyday of its success. Although dimly suggested by Newton as a possibility, there were difficulties, especially those connected with rectilinear transmission, that is, that light goes in straight lines. It was not at all easy to see how that could happen with waves. Waves do not act like that. Waves

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spread out round obstacles, curl round corners and edges. Sound waves do. How could light consist of waves? There were difficulties. That led Newton for the most part to abandon it in detail and develop the corpuscular theory—the view that little particles of light were shot out like bullets. That held its own until the wave theory was revived at the beginning of the nineteenth century by Huygens and by Thomas Young, who was soon afterwards appointed Professor at the Royal Institution of Great Britain in Albemarle Street, that wonderfully progressive Institution whose professors were released from systematic teaching and were able to devote all their energies to research. All the world knows that Thomas Young was succeeded by Humphrey Davy, who was succeeded by Faraday, and that discoveries thick and fast, both in chemistry and in physics, emanated from their laboratories and almost revolutionised science; besides having the result of initiating a new profession, that of electrical engineering. The time is coming, both in this country and in America, when there will be more of such research institutions, with adequate endowments, and scope for the brilliant young men who are never lacking to disentangle the secrets of Nature.

This, however, is a digression. What Huygens and Thomas Young did was to discover the principle of the interference of light, and to show how, on that principle, and by the aid of a simple geometrical construction, the rectilinear transmission of light could be explained on the wave theory, and also the whole theory of shadows, including the diffraction patterns and other interference bands, on which

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Newton himself had begun to experiment. The subject was taken up brilliantly and with enthusiasm in France, and to the great genius of Fresnel were due many of the developments that continued their influence throughout the nineteenth century, and have continued indeed to this day. There also, in France, the polarisation of light was discovered, which showed not only that light consisted of waves, but that, unlike the waves of sound, they were transverse waves, the oscillations occurring at right angles to the line of propagation. It was a moot question, however, whether the oscillations were in the plane of polarisation or at right angles to it. Fresnel held one view, McCullagh of Dublin another. You will see why I am taking these instances. They seem rather technical, but I think that they are pretty well known. I am only telling you the ancient history. The two views led to similar experimental results, and it was difficult to discriminate between them. The two views, classified as Fresnel's and McCullagh's, seemed in opposition to each other ; but ultimately they were reconciled by Clerk Maxwell, who showed that they were both true, and that the oscillations of light were electric in the one direction and magnetic in the other, a theory that is dominant and undoubted at the present day. It is well known that the waves emitted from a wireless sending station are polarised, electric oscillation in a vertical plane and magnetic in a horizontal one ; and detectors are arranged for both kinds of vibration, an elevated wire aerial for the electrical or vertical kind, a frame aerial for the magnetic kind, the energy in both kinds of vibration being

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equal, and the two oscillations being in the same phase, a condition essential to the transmission of radiation in one direction. So the corpuscular theory of light seemed to die a natural death, being finally to all appearance exterminated by that experiment of Foucault, which showed experimentally that the velocity of light in water was lower than that in air or space, whereas the corpuscular theory required that it should be greater in a dense medium.

Nevertheless there were some physicists who declined to abandon corpuscles, and one of them was a Professor at University College. When I came here in the 'seventies of last century the Professor of Physics was our good and well-beloved friend Carey Foster, who, after his retirement as Professor, became for a short time Principal of this College, and whose judgment on all University matters was highly valued by the Senatorial and other bodies of which he was a member. Carey Foster has inscribed his name on all accurate electrical engineering by his invention of the Carey Foster bridge, an ingenious modification of the Wheatstone bridge, which is invariably used for the accurate determination and standardisation of the units of resistance, the standard ohm, the corporeal unit at the basis of all our volts and amperes and watts that everybody is familiar with—at least as names—to-day, although they were not invented when I was here. Those standards were first in the custody of Sir Richard Glazebrook, and they are now stored in the National Physical Laboratory at Teddington. To compare them, the most accurate method is the Carey Foster bridge.

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In the old days Carey Foster told me chaffingly that he had been appointed Professor of Physics, although up to that time his best-known work had lain in a chemical direction, because he did not know too much mathematics, and because his predecessors, J. J. Sylvester and Richard Potter, had known too much, and had not been very successful as teachers in consequence. The interesting thing about Professor Richard Potter is that he was a belated upholder of the corpuscular theory of light, and the books he has left behind on physical optics are all couched in terms of that theory, which was by others abandoned. It only shows how important it is not to abandon any working theory prematurely, even when one is left behind by the progress of science as a minority of one; for during the present century, or the few years of it that have so far gone, the corpuscular theory of light has reared its head again under the name of the quantum theory. It has been developed by Sir J. J. Thomson and others, and in spite of many outstanding difficulties refuses to be ignored. At the same time the wave theory of light holds the field. They seem in opposition to each other. But, like the opposition theories of Fresnel and McCullagh, they are, perhaps, only waiting for another Clerk Maxwell to unify them and show that both are true, though doubtless in a form that neither side could have anticipated. I imagine that Professor Potter would have been, and perhaps is, very pleased at this long-deferred and only half-worked-out development.

During the nineteenth century we thought we knew a great deal about light, although it is true

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that we could not form a satisfactory dynamical picture of its oscillations, in spite of the masterly attempts of Lord Kelvin and others. We were always trying to make a model of ether and light in terms of matter, in terms of material things, wheels and elastic strings, and so on. Now we have learned that we cannot do that. You cannot explain ether in terms of matter. It would be an upside-down process. Ether is a much more fundamental thing. You have to explain matter in terms of ether. The mechanical models, although ingenious, although they went a certain way, always failed. You could not work the mechanical theory of light. The oscillations were not mere vibrations. Maxwell showed us that they were electric vibrations. Then we tried to make models —I myself tried—of electrical actions, magnetic actions. You cannot do it, or not satisfactorily. They belong to that other more fundamental thing. We have to explain them all in terms of ether before we have done. It has not been done. We are under no delusion in that respect. We do not think that we know a lot about these things now, though we know a good deal more than we did in the nineteenth century. We are sure that a great deal more remains to be understood about the ultimate nature of ether vibrations.

This instance which I have taken from one domain of physics, for I cannot cover the whole ground and I thought it better to take a typical instance, is really representative of what has occurred all round. In the nineteenth century we thought that we knew a great deal about matter. The size, the mass, the speed, all about atoms,

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seemed thoroughly explored. The locomotion of matter seemed the simplest thing in the world. It is certainly that to which we are most accustomed. But he would be a bold man who said that he understood what locomotion was now, fundamentally. I do not know whether Professor Porter agrees with me. Anyhow, if we disagree it will not be the first time that people have disagreed. But I do not think that he does disagree, because he knows what I mean. I cannot expect everybody to know what I mean. The fact is that all this certainty has evaporated in a still wider and fuller knowledge, which, however, is not yet complete—not yet. The atom of matter has given way to the atom of electricity, or perhaps we should rather say that matter has been found identical with positive electricity, while negative electricity, which is a still more mobile variety, differs from it in many important respects. The electron might be called the unit of electricity, the proton might be called the ultimate unit of matter, and the structure of neither do we know. But here again ancient speculations of genius are justified. Benjamin Franklin, who made many electrical experiments, was imbued with the idea that the two things concerned were matter on the one hand and the electric fluid on the other. With certain modifications, more in language than in reality, that idea now holds the field. Thus, as we progress in physics, and, I daresay, in other subjects, we often find that the notions of our predecessors, whether in the positive or the negative direction, are more justified than we could have imagined probable or possible. Genius is a very curious thing, and a

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man of genius may be before his time; he may lay down things which are not understood, and ultimately it may be found that he was justified. You cannot say that the declarations of a genius are discoveries. No; the thing is discovered when it can be put into organised form and become a branch of science. But these intuitions are remarkable. Anyone who works at a subject for a long time, for a lifetime, is entitled to opinions, even if they are not orthodox and not universally accepted.

The general outcome of it all, this upsetting or return to old ideas, whichever way you like to put it, has been to cause the younger generation of physicists to root up most of our cherished convictions and examine and modify them before replanting them—a sort of root pruning, that botanists tell us is good for some kinds of fruit-bearing trees, and which ultimately results in a more plentiful crop. I doubt not that so it will be in this instance.

Now I just want to return to Professor Carey Foster and his repudiation of any extensive knowledge of higher mathematics. It is not to be supposed that the College at that time in any way lacked mathematical teaching. Only recently then had that greatest of all mathematical teachers, Augustus De Morgan, ceased from his tenure of the Chair, and the work was brilliantly carried on by Henrici, an admirable teacher of the German school, in pure mathematics, and in applied mathematics by that astonishing genius, William Kingdon Clifford, whose lectures, though comparatively unsystematic and irregular, were a delight and an inspiration. I could tell you many things about

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Clifford. He was often half an hour late for lectures. I remember his saying once, when he was going to give us an examination, "The worst of these examinations is that you have to think what to ask the fellows before you come in, whereas, when you lecture you need not think at all." His lectures were very brilliant and well worth waiting for, I can tell you; but very few people can do like that.

In chemistry we had that well-known chemist, A. W. Williamson, whom I saw and heard before I came here. He presided over the first British Association meeting I ever attended in Bradford in 1873. Williamson, you remember, was preceded by Graham, the discoverer of osmosis, the diffusion of liquids, a tremendously important subject—tremendously important in the human body and tremendously important in all living structures. The way that fluid goes from one cell to another, and the digestion of food and the way the sap rises to the tops of trees: these things are all explicable, though not easily explicable, in terms of the osmotic pressure of Graham. It is the foundation, I was going to say, of bio-chemistry. I think that it might rather be called the foundation of bio-physics. It is the beginning of bio-physics. If I was a young man—I do not know what I would do, but I commend the idea of bio-physics to some of you. Bio-chemistry has got its foot in as a new subject; but in the physics and chemistry of living organisms, there is a wonderful field of investigation there. I am not touching on biological things; I am not touching on any of the medical things. They will be dealt with by others more

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competent. But I should like to say that in physiology I used to see Professor Sharpey wandering about these corridors. I suppose that he was one of the most distinguished teachers of physiology in Europe. Whom had he among his pupils? Michael Foster, Burdon Sanderson, and Lister!

It was here that Schäfer also worked as a student: while Micaiah J. Müller Hill, Viriamu Jones, Forster Morley, Fison, and Ferranti were among my contemporaries. Sir Alexander Kennedy was the first Professor of Engineering, and he made the first Students' Engineering Laboratory in the basement down in the middle of the building, as Carey Foster had made one of the first Physical Laboratories for students. Sir Alexander Kennedy has not been very well lately; but I saw him yesterday in the Athenæum, and he told me that in four days more he would be eighty. Well, he did very good work for this place.

It was not so very long after I left that A. W. Porter came here from Liverpool. Henry Morley was the Professor of English Literature, I should think one of the most brilliant teachers that there could be. By his lecturing about the country he extended a love of literature throughout the length and breadth of the land. He was succeeded by W. P. Ker, and I gather from the Provost's Address that he was preceded by Arthur Hugh Clough, the poet, and by David Masson, so well known in the University of Edinburgh.

You have had most distinguished people, and I have no doubt that you have them still.

I remember showing in this very room one of the first phonographs that came over from Edison's

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Laboratory in America to one of the early meetings of the Students' Chemical and Physical Society. It was quite a novelty then, and people were satisfied with exceedingly bad intonation. In fact, you had to hear what was spoken into it in order to understand what came out of it. It would have seemed absurd to suppose that that instrument could ever have developed into the remarkably efficient and speed-regulated gramophones of the present day. But when a thing has started, when you have the nucleus, you never know what it is going to develop into. You may be quite sure that if there is any possibility of development, the ingenuity of man will work it out and make it a perfect thing, when it becomes an engineering instrument. As long as it stays in the physical laboratory you always have to tinker it up, and it is not foolproof. You have to send for the laboratory boy to put it right. At any rate, that is what the lady students usually do. There were no lady students when I first came here, or they were just beginning. The engineering faculty has to deal with an instrument before it is fit and finished.

It is a digression, but this morning I saw for the first time what some of you may have seen, or at any rate have heard about, namely, Mr. Baird's experiments in television. They are infantile at present in development ; but they have promise of more. I think that they are something like the kinematograph was when it first began, or like the phonograph was when it first began, or indeed like the telephone was when it first began. You cannot tell what any one of those things is going to become. I would not like to predict ; but I must say that it

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looks hopeful. It is more than just the telegraphing across of a photograph or a print. It is not like that. He was not telegraphing it. He could telegraph it, no doubt. But you could see a person sitting in the dark. It happened that he wanted me to see that it could be done in the dark. The person was not illuminated. He was in the middle of ether vibrations (that was essential); but the ether vibrations were not those which affect the eye. Certainly it was rather warm where the patient had to sit. You know that when you are seated in front of a fire you are feeling the ether quiver, the ether vibrations. In sunshine you feel the ether vibrations. Here you were feeling the ether vibrations. You did not see them, no; but there was a receptive instrument which, so to speak, did see them and did show them on the screen, small, rather flickering, not very distinct. You could see the person sitting in another room in the dark. You could see his face. You could see when he opened his mouth. You could see when he turned his head. You could see when he grinned at you. He could not see you. But he was told to do these things by telephone, and did them; and with a little difficulty, if you had known him very well, you might have recognised who he was. Now that seems to me to be a beginning. A lot of people have been working at it, and I suppose that others will be taking it up, and it will be going ahead sooner or later. I expect to see (you will see at any rate), ten or twenty years hence, that it has blossomed into something.

In my time, of course, there was no electric light in actual use, though the arc light had long

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been known in the laboratory; but Carey Foster and I saw the first Swan lamp exhibited in London at the Society of Telegraph Engineers. Soon afterwards Colonel Crompton, who is still active, brought over a number of storage batteries, which were then also in their infancy, and installed temporarily what was regarded as a surprising exhibition of incandescent electric lamps along the corridors at a University College conversazione.

It is interesting to remember that not only electric light but telephones and most of the other appliances now in daily use have come within my own lifetime, and even the birth of the telegraph cable, which, I suppose, you think we have had from time immemorial, the first one from Dover to Calais, was coincident with my own birth. I was fifteen or sixteen when the first permanent Atlantic cable was laid. Indeed, a hundred years ago even railways were in their infancy, while the beginning of radium and radio-activity and X-rays, and all that host of developments, even some of the younger members of this audience can remember.

The modern applications of science that are now commonplace are too numerous to mention. One would have to speak of radio-telegraphy, aeroplanes, and submarines, and things that were not dreamed of when this College was founded. But no one in this place will forget that the electric valve, now so essential in the radio-transmission of speech and music, a construction that has blossomed into extensive manufacture—they are manufactured now by the million—owes its origin to the discovery that such a valve could be used as a wireless detector, instead of a coherer, by your first Professor of

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Electrical Engineering, James Ambrose Fleming, who, I am glad to think, was a fellow student of mine in or about the year 1872 in Professor Frankland's Chemical Laboratories at the new Royal College of Science in South Kensington. Sir William Crookes was at work in those days, and Fleming and I were keenly interested in his radiometer, or rather in the early stages of research that led up to that instrument. We heard also that he was engaged in other less orthodox researches; but we turned up our noses at those other researches in those days. At a later stage, namely in the year 1879, when I was still here, before ever I went to Liverpool in 1881, Sir William Crookes electrified the world by his demonstration of cathode rays at the British Association Meeting in Sheffield, and by the remarkable devices that his command of high vacua enabled him to make, which afterwards blossomed into the discovery of X-rays by Röntgen, and were the subject of masterly mathematical treatment and further development by Sir J. J. Thomson, who, at the end of the century, capped the devices by his weighing and measuring and effectively discovering the electron, a minute element that has dominated physics ever since, and bids fair to be dominant long after even the youngest of us has passed on. That discovery was made just at the end of last century, a very good beginning for the present century.

Criticism and Anticipation

You see that my Address hitherto has been retrospective. I want a little prospect as well.

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There are many tendencies in modern science, and physics is becoming to some extent metaphysical, that is to say, it is having an influence on philosophy. I sometimes ask myself whether there is any tendency in philosophical physics which is to be deprecated; because it is quite possible, as you go on, to take a wrong turning or to go down instead of going up. It is possible to make mistakes. Now there is one doctrine that I think is wrong and that ought to be treated as a heresy. What I mean is this—the statement that physical laws, the laws of Nature, are not so much true as convenient, that when we formulate a law of Nature, or any great generalisation, we are only putting down a sort of convenient shorthand summary; in other words, that we are not out for truth but for usefulness. I suppose that the idea underlying this contention is that truth is beyond us. I do not know. It may be that the philosophers who say this are doubtful what is truth. It is an old question! From quite a recent number of *Nature* I make a quotation from the review of a book. This is it verbatim: "The question of true or false has no meaning in science. All that one is concerned with, as in the case of all scientific theory, is its usefulness." Now that is held by not unimportant people, yet I believe that it is entirely false, that it is a thing to guard against, that it is an idea to be contended against and fought as a heresy. I do not like the idea of heresies in science; but I think that that is one. We are out for truth. We may not get it, but that is our aim. I have written about it, and if anybody chooses to look at next week's *Nature* they will see what I have to

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say on the subject at more length, and so I will not amplify that.

The times in which we live are of the most extraordinary interest in physical science. Physical science has advanced during the last twenty-six years with amazing rapidity. It almost takes one's breath away to think of the discoveries that are constantly turning up now, and that have been turning up during these last few years.

I want to go back for a moment. Associated with this place, I said that Williamson was preceded by Graham, and I meant to say that, as you all very well know, he was succeeded by that very great chemist, Sir William Ramsay, who, on the other side of the quadrangle, discovered more gases than anyone since the time of Priestley. He was a most brilliant experimenter, and he discovered most of the inert gases. The first of them was discovered by Lord Rayleigh ; but very soon Ramsay took the subject up. The discovery of Argon was the beginning, and then Ramsay discovered Neon, Krypton, Xenon, and, effectively, terrestrial Helion. These things, which seemed so inert that some chemists almost objected to their being called chemical elements, because they had no chemical properties, have turned out really useful. I do not mind whether they turn out useful or not, but they have. At least Neon—if you call that useful—is used for shop signs and advertisements, is it not? and Helion is used as a light inflammable gas to fill balloons, and Argon is used for gas-filled lamps. I daresay that these lamps here in this theatre are full of Argon, if they are what are called half-watt lamps. That is very curious, again. How did

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these incandescent lamps begin? They began with a carbon filament manufactured by Swan, very ingeniously. There was considerable difficulty in getting a carbon filament, a thread of charred silk or cotton or whatever it might be, strong enough to hold together, to last some time, to be ignited by an electric current. You had to put it into a complete vacuum, or, of course, it would be burned or destroyed. But now we have returned to what would have seemed much simpler, namely, a metallic filament, and instead of putting it in a vacuum you put it in an atmosphere of inert gas, so that you have a gas-filled lamp and not a vacuum lamp, and the filament lasts all the longer if you only keep out oxygen and water vapour and so on, and employ dry Argon. These inert gases have turned out useful. But, whether useful or not, they are most important discoveries. They are the keynotes of the chemical octaves in the Mendelejeff series. They all ought to end in "on." They all do except Helium. That is why I call it Helion, and I want you people to call it Helion and pass it on, because it is one of the inert gases. The last is Emanation, though what name that will be called by hereafter I do not know. Ramsay called it Niton, Rutherford's disciples call it Radon. Those who have worked at the gases end in "on" too—J. J. Thomson, Aston, and other great men in Cambridge, Eddington and such-like. The discoveries of those gases were made here. They have had a great effect upon chemical discovery.

Investigation of the structure of the atom showed that atoms are the neatest and most compact of all

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structures. You know that atoms are built up of electrons revolving in orbits. The chemically active elements have cometary orbits stretching out into space, and look rather untidy. The inert ones have nothing of that sort. They are all nice and symmetrical and make a sort of rose pattern. You see them depicted in books. It is marvellous that the structure of the atom can be depicted with anything like a reasonable chance of approximate correctness. The orbits inside the atom can be calculated, and the shapes determined, and the rates of vibration known. So matter has taken on a different aspect altogether from what it did in my youth. An atom is like a solar system, and a solid body is like a Milky Way. Astronomy is penetrating into the interior of matter, and the Newtonian laws enable us to determine the mass of these things.

In astronomy what discoveries have been made? Quite recently that great man Dr. Jeans told us, I think in the very last number of *Nature*, or the one before, that his theory of spiral nebulæ had been confirmed by Professor Hubble from observation. These spiral nebulæ are the most remarkable things in the sky. You see only very few of them with the naked eye, but you see a great number with a large telescope, and with the 100-inch telescope in California, assisted by sensitive photographic plates which you can expose for hours, you can see, far away in the depths of space beyond imagination, faint, faint objects, all with the same structure, whirling masses of gas, which are in the birth throes for a constellation of stars. Each of those nebulæ evolves not a solar system, it is far too big

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for that, but a whole constellation of solar systems.

A century ago we did not know for certain that the stars were not all at the same distance approximately. We might have guessed that they were not, and that the faint stars were more distant. But it is since this College was founded that stellar discoveries have been made and the distances measured. No star's distance was known then, and how it was that they did not change in apparent position as the earth went round its orbit was a puzzle. Now we know the distances of a great many of them; and even the distances of the spiral nebulæ, far beyond our system, are becoming known by indirect methods. The Milky Way is our spiral nebulæ; our nebula is the Milky Way. It is an enormous thing. There is no reason to suppose that it is particularly bigger than some of the others. It is a unit, and beyond are other units. In Andromeda you can see with the naked eye something which is about as big as the Milky Way. It is just a wisp of light. What possibilities are there in these great structures? What is going on there? We find the same system of law and order, we find the same chemistry, the same physics, as here, the same atoms. They are all parts of this universe. Then farther off you see a fainter one and a fainter one and a fainter one, hundreds, thousands, millions of them. According to the latest ideas of Jeans, who on this whole matter is the great authority, they are roughly of the same size, and they are only faint because they are so far away. The faintest, in a 100-inch telescope photograph, is now estimated at 140 million light years away,

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that is to say, we see it as it was 140 million years ago, and all that time the light has been coming.

The universe is practically infinite. It is perfectly amazing how our conception of it has enlarged in my own lifetime. So nobody should take a small view of it. These revelations in science that are going on are all most interesting and will be most helpful.

We are celebrating this year the Bicentenary of Newton. I had an article on Newton in yesterday's *Observer* which you might choose to look at. I there touched upon the relation between Newton and Einstein, and all that modern upheaval. The younger physicists are pulling things up by the roots, as I said, and overhauling them before putting them back. There is Einstein with his relativity. Relativity is a great mathematical method, most ingenious and very difficult. But there is a tendency to look at these things from the philosophical point of view, from the real physical point of view, and to make statements which are not thoroughly justified. Many people think that the theory of relativity abolishes the ether. The ether is not so easily abolished as that. When you look at the thing mathematically you do not mention the ether, you work out the equations and you get results; but when you look at the thing physically you must have a connecting medium between the bodies. They are separate, more separate than ever. Discontinuity is in the air. The stars are separate from each other, the atoms are separate from each other, the electrons are separate from each other. What is holding them together? Gravity, cohesion, electric and magnetic forces, all

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these things. But where are these forces? What is the vehicle of these forces? I do not care by what name you call it, call it space if you like, but it is space with physical properties. I do not think that Einstein disagrees with that, for Einstein fully admits the need of an ether, when you come to look at it philosophically. He does not want it mathematically. Eddington agrees with it. The ether is all right. We are using it a great deal more than we know. People are using it for wireless. You are using it. . . . If I were to tell you all—well, I will some day. We are using it a great deal.

Anticipation in Physics

If you ask me what I think the future of physics is going to be when we are celebrating the Bicentenary of this University College, I think you will find that it is what I may call the hydrodynamics of the ether, the theory of vortices applied to the perfect fluid. Hydro-dynamics is very interesting when applied to a real perfect fluid, because ordinary fluids do not behave nicely; they have all got some viscosity; but ether has not. I believe that we shall find that the theory of vortices holds in a remarkable way, and to you young mathematical physicists I should say, Go for the theory of vortices and for the theory of gyrostats, spinning tops. There is a lot in them. The universe is going to be explained in terms of vortices in a perfect fluid (this is a rash prophecy) moulded here and there into spinning tops or gyrostats. There was a remarkable paper which emanated last Autumn from Professor Basil King of Montreal about the spinning electron. We have

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hitherto attended mainly to the electron as the unit electric charge, but, if it is spinning, everything that has to do with spinning suggests magnetism. The electron has not only electric properties; it is going to have magnetic properties too. We call it the spinning electron: I call it an electrified magnet. Work out a theory of electrified magnets in free space. It is no end of a job. You have electric repulsion and you have magnetic attraction, and you can make up beautiful patterns. I say that you can. I do not think that I could. I am too old. There is a lot of work in it. I venture to think that it is going to get over some of the outstanding difficulties of the quantum and of Bohr's theory of the atom. We have never quite understood why the radiation from the atom was proportional to a frequency, or indeed how any atom radiated. I do not suggest that Professor King has solved it finally, but he has written a suggestive paper. He has shown—in consequence of what we knew before—that an electron travelling along would be an oblate spheroid like the earth, and surmises that it suffers precession like the earth. You all know about the precession of the equinoxes. Newton explained that. It is due to the oblateness of the earth and the uncentric pull of the sun upon it. What is there in the electron to do that? It is an oblate spheroid if it is spinning, and also if it is travelling fast. According to King's theory, it is always trying to get its nose in front, it is always trying to get its axis in the line of advance. Whenever there is a deflecting force of that kind acting on a spinning top or a magnetic thing, it does not obey that force; it goes round, it precesses; just

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as with a bicycle, if you are tumbling over in one direction, you go round, you precess. A precession is the motion of a non-sleeping top. If a top is upright it need not precess, but if it is a slanting top gravity is trying to pull it down; but it does not go down, its axis goes round and round in a cone. That is precession. That is what the earth is doing. The earth's axis revolves round once in twenty-six thousand years or so. This top will go round quicker than that. It is Professor Porter's top, and I will ask him to spin it.

There is the top, and *here* is a weight that has been hung on it. It is balanced except for this weight. Suppose that I lift that weight. Now it is happy and quiet. It has gone to sleep. I let the weight on again. The weight tries to pull it over. Instead of falling over it turns round. Suppose that I press harder. It goes round quicker. It even gets up against my pressure. It does the queerest things. It does not like being pressed down. I was moving it a little quicker than it ought to go: that is what made it get up. I take the weight off. Now it is still. You think that I am holding it still, but I am not.

The earth is doing that kind of movement, and lots of things are doing it. The atoms are doing it. The electrons are doing that. This is a sort of spinning electron made of metal. It is a metal model. It will not do, I agree. You cannot explain these things in terms of matter; but you can illustrate them, and the laws of that are worth while working at. Gyrostats have been employed for various practical purposes, and so I suppose that people do attend to them now. That pre-

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cessional motion occurring in the electron due to its locomotion is what King thinks causes radiation. He argues that it would radiate, and would radiate at the right frequency, and that the radiation is proportional to the frequency.

I have tried elsewhere to indicate the lines on which I think an explanation of the outstanding phenomena is coming—an ultimate continuity in the midst of all this discontinuity, the ultimate continuity being the ether; and I conceive that on these lines, the lines of electrified magnets and spinning mechanism and vortices, the physics of the future will be based, and we shall get a still more luminous conception of the material universe.

I think that the ether is the instrument, the vehicle of life, that it is that that we really inhabit. I think that it probably has not only a material interaction, but a mental and spiritual interaction. Here I am leaving the ground of physics. You will think that I am merely speculating. Well, I have been speculating as to what the scope of future physics will be in prospect. I think that science is only beginning to realise, what religion has always realised, namely, that there is a spiritual universe too, and that those who founded this College and required no theological tests, but left that subject open, were right and wise. They left it to truth to make its way. Depend upon it, truth will make its way. If these things are true, and if there is a spiritual world as well as a material world, and if the two interact in a way in which I know they do interact, then I say that by patient plodding along the scientific road we shall arrive at that truth in due time, when the time is ripe. There was a time

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when there was no freedom for teaching; you had to teach along official lines. Now you have this academic freedom—not perhaps quite. I think that there may be some subjects that are still beyond the pale; but that will not last much longer. Truth will make its way, is making its way, and it rests with you younger men and women to see that it has a fair chance. Keep your minds open, avoid credulity, avoid undue negative assurance, be guided by the facts, make sure of the facts, do not exclude facts on the ground of any preconceived opinion, and then there will be a splendid prospect. I believe that there is a splendid prospect dawning before humanity, and that some of you will help it on and live to see it long after we elders have gone.

PROFESSOR ALFRED W. PORTER: Mr. Provost, Ladies and Gentlemen, it is with quite exceptional pleasure that I rise to move a vote of thanks to Sir Oliver Lodge, because amongst the things he did not state, as not being worth stating, is the fact that he is my old teacher of physics. I was specially fortunate in being a student at Liverpool under Lodge just at the time when he was most active in connection with his pioneer investigations on electric waves, for it must not be forgotten that at the same time Hertz was at work in Germany on electric waves Lodge was at work in Liverpool on another side of the same subject. No one can overestimate the importance of that work, for it has led to the modern telegraphy, wireless telegraphy and wireless telephony, of which he did make some mention. But there is one other investigation of his to which he did not refer. That is his attempt to move the

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ether. He has spoken of the ether as being a very fundamental thing in the world. Among his other investigations was the attempt to set it in motion. This was just after I left Liverpool, by the way. He had a huge disc that could be set rotating. The idea was to prove whether this disc drew the ether along with it or not. Do what he could, he did not succeed in making the ether budge at all. Thereby he, whether willingly or unwillingly, helped to lay the foundation for the upheaval, I think he called it, of to-day which is represented by the principle of relativity.

Amongst all his other qualities, Lodge is famous as being an expositor. We have had an example to-night of his genius for exposition. I have listened to long discussions at the British Association and elsewhere which apparently were leading to nothing. One after another has got up and merely made the clarity of the subject worse than he found it. Then Lodge has got up, and then everything has been perfectly clear; at least it seemed so to me. It is for his exposition to-night on some of the advances that have been made in physics and allied subjects that I rise to move that a vote of thanks be accorded to him. (Applause.)

The Chairman: I think that I may say that that vote is carried unanimously.

Sir Oliver Lodge: Professor Porter has perhaps seemed to suggest that I wanted to move the ether. I did not want the one thing or the other. I just wanted to find out if you could move it. I did not much think that you could. I was not disappointed. If the ether had been dragged along by matter

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it would have complicated things fearfully. It would have upset the theory of aberration and much else. The ether would have been a viscous fluid. What we proved was that it was not an appreciably viscous fluid. The probability is that it is perfectly non-viscous. Suppose that it were viscous, and suppose that it had any dissipation of energy, which is what ordinary fluids have, then its ripples would die away and turn into heat. They do not do that in the ether. If they did, do you think that you would see those distant nebulæ? No; it would be partially opaque. After travelling say a million years the light would be washed out. There is nothing of that kind. It is a perfect substance. The ultimate substance must be perfect. There is no frittering away of energy. There is nowhere for it to go to. It must be simply passed on. I am making waves now in the air. They are all mopped up by you and turned into heat. That is because there are foreign bodies present. Even if I was talking in a free atmosphere—you must have atmosphere or you cannot make any sound—if I was talking in the open air, the completely open air, it would still be frittered away, and the air would be a little warmer than before. What happens when a steamship crosses the Atlantic? It wastes all its energy in churning it up and making the water a little warmer than before, a very little warmer. That is what dissipation of energy is—just waste, or apparent waste. But none of these things go on in the ether. The result is that it is calculated to do all that is wanted and a great deal more. The electrons and all the other things, and our own brains, and the connection between brain and

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muscle, and the way the body is held together, all depend on the ether. The ether is the universal connecting medium. Matter is the thing you can move. I should define matter in that way—that which can be moved, in the sense of locomotion. The ether you cannot move. You can only strain it. All potential energy is in the ether; all kinetic energy is in matter.

But here I am beginning a course of physics. There are some physicists here. I am glad to lay my bones among you, as it were—the remains of a long life devoted to this kind of studies, and I assure you that if you do not find those things that I have said true you will find something better.

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